F1

Islamic University of Gaza
Water Resources Management
EENV3352
Second Semester (2010-2011)
Allowable time 75 minutes

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CLOSED BOOK EXAM

Student Name: ____________________ Student No.: ________________

Q1		**5**
Q2		**5**
Q3		**4**
Q4		**6**
Q5		**10**
Total		**30**

Question 1 **(5 Marks)**

1) Darcy law is valid, when the flow is:
(a) Laminar b) turbulent c) both (a) and (b) d) none of these

2) Groundwater is found to occur in the geological formation which is
a) Porous b) Permeable (c) both (a) and (b) d) None of these

3) The water wells excavated through confined aquifers are known as:
a) Artesian wells b) pressure wells (c) both (a) and (b) d) none of these

4) The discharge per unit drawdown at a well is known as:
a) Specific yield b) Specific retention (c) Specific capacity d) Specific storage

5) Specific Yield for an unconfined aquifer is:
a) greater than porosity (b) less than porosity c) equal to porosity
d) unrelated to porosity

p2

Question 2: **(5 Marks)**

The volume of a wet soil sample is 2000 cm^3. The volume of water drained from the sample by gravity was 500 cm^3. After drying the drained soil in the oven, the volume was 1350 cm^3.

Compute:

i) **the specific retention,** Sr

ii) **specific yield, and** Sy

iii) **porosity of this soil** α

$V_T = 2{,}000\ cm^3$, $V_W = W_W = 500\ cm^3$, $V_S = 1{,}350\ cm^3$

$$\alpha = \frac{V_V}{V_T} = \frac{V_T - V_S}{V_T} = \frac{2{,}000 - 1{,}350}{2{,}000} \Rightarrow \boxed{\alpha = 0.325}$$

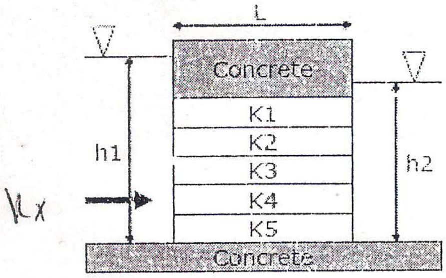
$$S_y = \frac{V_W}{V_T} = \frac{500}{2{,}000} \Rightarrow \boxed{S_y = 0.25}$$

$$S_r = \frac{(2{,}000 - 1{,}350) - 500}{2{,}000} \Rightarrow \boxed{S_r = 0.075}$$

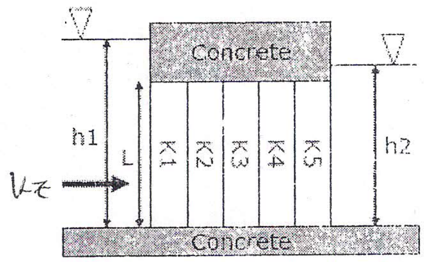
$$S_r = \alpha - S_y \Rightarrow S_r = 0.325 - 0.25 = \boxed{0.075}$$

Question 3: **(4 Marks)**

Consider the two formations of five different soil layers (Part A: layers are vertically distributed and Part B: Layers are horizontally distributed) with their own hydraulic conductivities. K1 to K5 are 5, 10, 8, 25, and 2 m/day, respectively. The thicknesses (b) of them are 3, 2, 6, 4, and 1 m, respectively. Assume that a concrete layer is impermeable; **Dose Part A has higher equivalent hydraulic conductivity than Part B?**



Part A



Part B

Part A:

$$K_{eq} = \frac{K_1 b_1 + K_2 b_2 + \dots + K_n b_n}{b_1 + b_2 + \dots + b_n}$$

$$\Rightarrow K_{eq} = \frac{5*3 + 10*2 + 8*6 + 25*4 + 2*1}{3 + 2 + 6 + 4 + 1} \Rightarrow \boxed{K_{eq} = 11.5625}\ m/d$$

Part B:

$$K_{eq} = \frac{3+2+6+4+1}{\frac{3}{5} + \frac{2}{10} + \frac{6}{8} + \frac{4}{25} + \frac{1}{2}} \Rightarrow \boxed{K_{eq} = 6.37}\ m/d$$

Question 4: **(6 Marks)**

Piezometer data were collected from the three observation wells in a confined aquifer as follows:

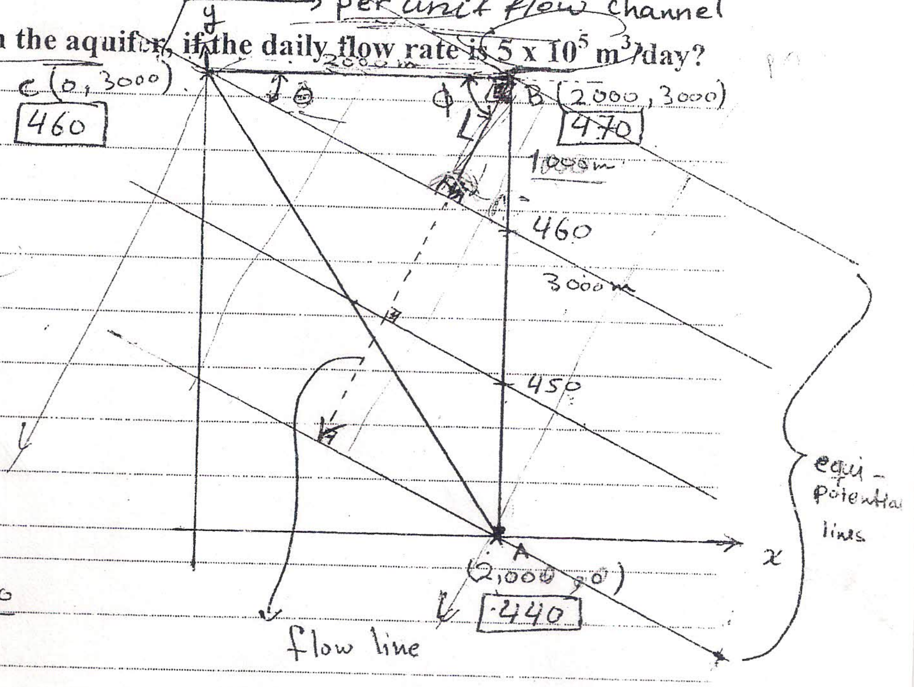
Well	X (m)	Y (m)	Ground surface elevation (m)	Depth to water (m)	Piezometric Head (m)
A	2000	0	480	40	480 - 40 = 440
B	2000	3000	610	140	610 - 140 = 470
C	0	3000	545	85	545 - 85 = 460

$T = \frac{nQ}{mh}$ (470-440)

i) **Calculate the hydraulic gradient.** $I = \frac{\Delta h}{L}$

ii) **Draw the flow net and determine the direction of groundwater flow through the triangle ABC?**

iii) **Estimate the Transmissivity in the aquifer, if the daily flow rate is 5 x 10^5 m^3/day?** → per unit flow channel



$\theta = \tan^{-1}\left(\frac{1000}{2000}\right)$

$\Rightarrow \theta = 26.57°$

$L = ?? \Rightarrow \sin\theta = \frac{L}{2000}$

$\Rightarrow L = 2000 * \sin(26.57)$

$\Rightarrow L = 894.4$ m

$I = \frac{\Delta h}{L} = \frac{470-460}{894.4}$

$\Rightarrow I = 0.01118$

$\phi = 90 - 26.57 \Rightarrow \phi = 63.43°$ with x-axis

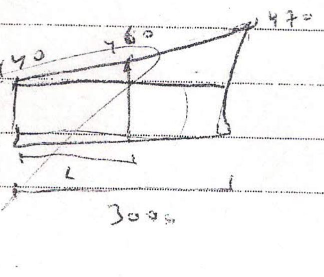
$T = \frac{nQ}{mh}$

(III) $T = ??$, $Q = 5 * 10^5$ m^3/day

$T = \frac{n Q}{m h}$, using $\Rightarrow h = 470 - 460 = 10$ m $\Rightarrow n = 1$

$T = \frac{1 * 5 * 10^5}{1 * 10} = 50{,}000$ m^2/d (per unit flow channel)

$\frac{460-440}{L}$, $\frac{470-440}{3000}$



$\frac{20}{L} = 0.01$

Question 5: **(10 Marks)**

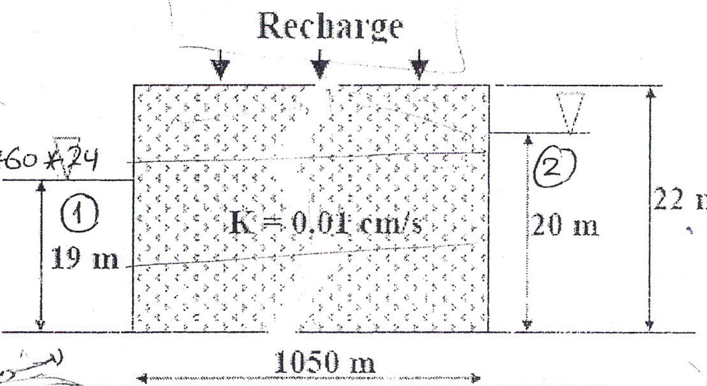
The water levels of two rivers are 19 and 20 m in the following aquifer system. The width of aquifer is 1050 m, hydraulic conductivity is 0.01 cm/s, effective porosity is 0.3, the current mean net recharge to the aquifer is 365 mm/year, and the elevation of ground surface is 22 m. It is required to maintain at least 1 m thickness from the ground surface for crop aeration in unsaturated zone. Consider the following figure,

i) **Compute the highest level of water table (m) and its location (m) in the aquifer under current mean net recharge rate?**

ii) **Compute the flow rate per unit width of aquifer to each river under the current mean net recharge rate?**

iii) **Compute the maximum possible mean net recharge rate (mm/year) before the condition violates the aeration requirement of 1 m thickness?**

iv) **Compute the average travel time (years) of water from the maximum head location to the low river?**



(I)

$W = 365 \text{ mm/year} = \frac{365 \times 10^{-3}}{365}$

$\Rightarrow W = 1 \text{ mm/d} = 0.001 \text{ m/d}$

$K = 0.01 \text{ cm/s} = 0.01 \times 10^{-2} \times 60 \times 60 \times 24$

$\Rightarrow K = 8.64 \text{ m/d}$

$d = \frac{L}{2} - \frac{K}{W}\frac{(h_1^2 - h_2^2)}{2L}$

$\Rightarrow d = \frac{1050}{2} - \frac{8.64}{1 \times 10^{-3}}\frac{(19^2 - 20^2)}{2 \times 1050} \Rightarrow d = 685.46 \text{ m}$ from river ①

$h_{max}^2 = h_1^2 - \frac{(h_1^2 - h_2^2)d}{L} + \frac{W}{K}(L-d)d$

$= 19^2 - \left(\frac{19^2 - 20^2}{1050} \times 685.46\right) + \frac{0.001}{8.64}(1050 - 685.46)(685.46)$

$= 415.38 \Rightarrow h_{max} = 20.38 \text{ m}$

(II)

River ① $x=0$

$q_1 = 8.64 \times \frac{(19^2 - 20^2)}{2 \times 1050} - 0.001\left(\frac{1050}{2} - 685.46\right) = 0.686 \text{ m}^3/\text{d/m}$ to river ①

River ② $x=1050$

$q_2 = 8.64 \times \frac{(19^2 - 20^2)}{2 \times 1050} - 0.001\left(\frac{1050}{2} - 1050\right) = 0.36 \text{ m}^3/\text{d/m}$ to river ②

(IV) $t = ??$ $\Rightarrow$ to the low river $\Rightarrow$ distance $= d = 685.46$ m

$t = \frac{L}{v_\alpha}$, $v_\alpha = \frac{v}{\alpha}$, $v = KI \Rightarrow v = K\frac{\Delta h}{\Delta L}$

$\Rightarrow v = 8.64 \times \frac{20.38 - 19}{685.46} \Rightarrow v = 0.0174 \text{ m/d}$

$v_\alpha = \frac{0.0174}{0.3} \Rightarrow v_\alpha = 0.058 \text{ m/d}$

$\Rightarrow t = \frac{685.46}{0.058} \Rightarrow t = 11{,}818 \text{ days} = 32.38 \text{ years}$

(III) W_{max} (mm/year) Fs

$\Rightarrow h_{max} = 21\,m$

$$\Rightarrow h_{max}^2 = h_1^2 - \frac{(h_1^2 - h_2^2)}{L} d + \frac{W}{K}(L-d)d$$

$$d = \frac{L}{2} - \frac{K}{W}\frac{(h_1^2 - h_2^2)}{2L}$$

$$\Rightarrow d = \frac{1050}{2} - \frac{8.64}{W}\frac{(19^2 - 20^2)}{2 * 1050}$$

$$\Rightarrow \boxed{d = 525 + \frac{0.16}{W}}$$

$$\Rightarrow (21)^2 = (19)^2 - \left[\frac{19^2 - 20^2}{1050}\left(525 + \frac{0.16}{W}\right)\right] + \left[\frac{W}{8.64}\left(1050 - \left(525 + \frac{0.16}{W}\right)\right) * \left(525 + \frac{0.16}{W}\right)\right]$$

By trial and error:

$W_{max} = 0.00185\ m/d \Rightarrow \boxed{W_{max} = 675\ mm/year}$

$$\frac{0.00185\,m}{1\,day} \frac{\times 360}{10000}$$

Formulae Sheet

$$K_z = \frac{z_1 + z_2 + \cdots + z_n}{\frac{z_1}{K_1} + \frac{z_2}{K_2} + \cdots + \frac{z_n}{K_n}}$$

$$Q = m\,q = \frac{Kmh}{n}$$

$$K_x = \frac{K_1 z_1 + K_2 z_2 + \cdots + K_n z_n}{z_1 + z_2 + \cdots + z_n}$$

$$T = \frac{nQ}{mh}$$ flow nets

$$\alpha = \frac{V_v}{V} = \frac{V_t - V_s}{V_t}$$

$$K = \frac{\alpha L^2}{ht}$$ tracers

$$q = \frac{K}{2x}\left(h_0^2 - h^2\right)$$ Steady unconfined

$$h^2 = h_0^2 + \frac{W}{K}\left(a^2 - x^2\right)$$ Steady unconfined

Baseflow $$h^2 = h_1^2 - \frac{\left(h_1^2 - h_2^2\right)x}{L} + \frac{W}{K}(L - x)x$$

$$q_x = \frac{K\left(h_1^2 - h_2^2\right)}{2L} - W\left(\frac{L}{2} - x\right)$$ Baseflow

Baseflow $$d = \frac{L}{2} - \frac{K}{W}\frac{\left(h_1^2 - h_2^2\right)}{2L}$$

$$Q = 2\pi K b \frac{h - h_w}{\ln(r/r_w)}$$

$$T = \frac{Q}{2\pi(s_1 - s_2)}\ln\frac{r_2}{r_1}$$

$$T = Kh_0 = \frac{Q}{2\pi\left[\left(s_1 - \frac{s_1^2}{2h_0}\right) - \left(s_2 - \frac{s_2^2}{2h_0}\right)\right]}\ln\frac{r_2}{r_1}$$

$$h_0^2 - h^2 = \frac{W}{2K}\left(r^2 - r_0^2\right) + \frac{Q_w}{\pi K}\ln\frac{r_0}{r}$$

$$K = \frac{Q}{\pi\left(h_2^2 - h_1^2\right)}\ln\frac{r_2}{r_1}$$

$$h = -\frac{vx}{K}$$ Steady confined